

It's only a matter of time before south Louisiana takes a direct hit from a major hurricane. Billions have been spent to protect us, but **we grow more vulnerable every day.**

Washing away

| PART ONE OF A FIVE-PART SERIES |



HURRICANE IMAGE FROM NOAA POLAR ORBITING SATELLITES; LAND IMAGE FROM NASA'S TERRA SATELLITE/STAFF ILLUSTRATION

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Stories by John McQuaid and Mark Schleifstein Staff writers • **Photos by Ellis Lucia** Staff photographer • **Graphics by Daniel Swenson** Staff artist

IN HARM'S WAY

With the land around us constantly sinking, our natural storm protection is disappearing. Levees protect us, but they're not enough.

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Even a weak hurricane can devastate towns closer to the coast. A new levee will protect some but leaves out others.

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If Hurricane Georges hadn't swerved in '98, parts of Orleans, Jefferson and the River Parishes could have been underwater.

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EVOLVING DANGER

Scientists now say we're even more vulnerable than we thought. But no one knows how much more.

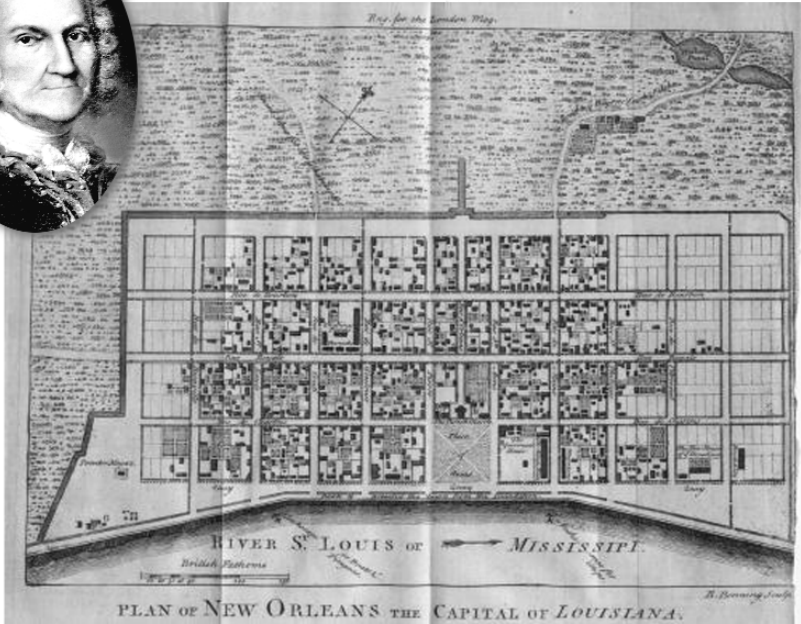
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NATURE'S WEAPON

From humble beginnings in the Atlantic, storms grow into hurricanes with as much energy as 15 atomic bombs.

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WASHING AWAY



FATEFUL DECISION • Nearly 300 years ago, Jean Baptiste le Moyne, sieur de Bienville, settled along a strip of land between the Mississippi River and the marshes south of Lake Pontchartrain. While the location would prove ideal for commerce, it left the city vulnerable to hurricanes and flooding.
HISTORIC NEW ORLEANS COLLECTION

In Harm's Way

Surging water is the biggest threat to south Louisiana. The land around us is inexorably sinking, leaving coastal areas more exposed than ever. While levees protect urban areas, they won't hold back a catastrophic storm. And once the water gets in, it can't get out, leaving a fetid mess for months. After three centuries of carving out a home surrounded by water, we're almost as precariously perched as when Bienville settled along this crook of the Mississippi.



STAFF PHOTO BY ELLIS LUCIA

Water is never far from New Orleanians. Just outside the city, saltwater intrusion is destroying marshes, including this one near the Bayou Bienvenue-Florida Avenue Canal between New Orleans and St. Bernard Parish. Now that cypress trees and other vegetation have died, erosion will accelerate, further stripping the region of its natural protection against hurricanes.

**By John McQuaid
and Mark Schleifstein**

Staff writers

ON the night of Aug. 10, 1856, a powerful hurricane struck Last Island off the southern tip of Terrebonne Parish. The sea rose in the darkness and trapped hundreds of summer vacationers visiting the popular resort. Wind-driven waves 8 feet high raked the island and tore it in two.

By morning, everything standing upright was broken, splintered and washed away, including all of the island's trees, its casinos, a hotel and the summer homes of wealthy New Orleans families. More than 200 people died. Many were crushed and others drowned after being struck by

wreckage in the maelstrom.

Claire Rose Champagne's great-great-grandmother Amelie Voisin and a baby daughter were among those lost in the storm. Other family members survived and eventually abandoned Last Island — today the Isles Dernieres archipelago — for Dulac, a fishing village 30 miles inland up Bayou Grand Caillou. But there was no escape from the storms, which have followed the family inland over five generations.

In 1909, Champagne's fisherman grandfather was out at sea when another hurricane lashed the Louisiana coast with 110-mph winds that propelled a 10-foot wave of water through Dulac.

"My grandmother and (her) children were left at home and saved themselves by climbing into the attic of the house," she said. "Forty people

tied ropes to the house and to two oak trees, then all stayed in the attic — women and children and some men. After the hurricane the government sent some tents for people to live in." Her grandfather made it back alive, but about 350 people along the coast died in the storm.

Hurricanes are a common heritage for Louisiana residents, who until the past few decades had little choice in facing a hurricane but to ride it out and pray.

Today, billions of dollars worth of levees, sea walls, pumping systems and satellite hurricane tracking provide a comforting safety margin that has saved thousands of lives.

But modern technology and engineering mask an alarming fact: In the generations since those storms menaced Champagne's ancestors, south Louisiana has been growing more

vulnerable to hurricanes, not less.

Sinking land and chronic coastal erosion — in part the unintended byproducts of flood-protection efforts — have opened dangerous new avenues for even relatively weak hurricanes and tropical storms to assault areas well inland.

"There's no doubt about it," said Windell Curole, general manager of the South Lafourche Levee District, who maintains a hurricane levee that encircles Bayou Lafourche from Larose to the southern tip of Golden Meadow. "The biggest factor in hurricane risk is land loss. The Gulf of Mexico is, in effect, probably 20 miles closer to us than it was in 1965 when Hurricane Betsy hit."

These trends are the source of a complex and growing threat to everyone living in south Louisiana and to the regional economy and culture:

► The combination of sinking land and rising seas has put the Mississippi River delta as much as 3 feet lower relative to sea level than it was a century ago, and the process continues. That means hurricane floods driven inland from the Gulf have risen by corresponding amounts. Storms that once would not have had much impact can now be devastating events, and flooding penetrates to places where it rarely occurred before. The problem also is slowly eroding levee protection, cutting off evacuation routes sooner and putting dozens of communities and valuable infrastructure at risk of being wiped off the map.

► Coastal erosion has shaved barrier islands to slivers and turned marshland to open water, opening the way for hurricane winds and flooding to

Death estimates in city would dwarf earlier hurricanes

HURRICANE, from Page 3

Mississippi River delta's, the surge doesn't rise as high but can penetrate dozens of miles inland. There currently is no defense against a surge from a major storm, a Category 4 or Category 5 hurricane on the Saffir-Simpson scale used by meteorologists. Such storms can generate surges of 20 to 30 feet above sea level — enough to top any levee in south Louisiana. Sustained winds from major storms — 131 mph to 155 mph for a Category 4, even more for a Category 5 — can shred homes and do damage to almost any structure. Fortunately, such storms are relatively rare events. Hurricane Camille, which struck the Mississippi Gulf Coast in 1969, and an unnamed 1935 storm that hit the Florida Keys were the only Category 5 storms to strike the U.S. coast in the past century. Fifteen Category 4 hurricanes made landfall on U.S. soil during that time. For lesser, more common storms, natural and man-made defenses exist, such as levees to keep out storm waters, and barrier islands and marshes also block and dampen storm surges.

Levees choke delta growth

The problem for south Louisiana is that the natural protections are rapidly deteriorating, and that in turn is weakening man-made defenses, mainly because the entire delta region is sinking into the Gulf of Mexico. The Louisiana coast resembles a bowl placed in a sink full of water. Push it down, or just tip it slightly, and water rushes in. Inland areas now see deeper flooding more often from storms. Tropical Storm Frances pushed a 4.5-foot storm surge into St. Charles Parish in 1998, putting U.S. 90 under water for a week, for example. The coast's sinking profile has emergency managers fretting that low points will be cut off during an evacuation — including Interstate 10, which drops 12 feet below sea level at the railroad underpass near the Jefferson Parish line. "The big thing that has put coastal processes in fast forward here in Louisiana relative to other systems is the rapid sinking of the land, subsidence," Louisiana State University coastal geologist Greg Stone said. "That makes it a fascinating place. What takes centuries to millennia in another place, here is happening in a decade."

Sinking is largely a natural process: The earth deposited by the river crushes the soft soil below it, and abandoned delta areas slowly disappear under water. But humans have accelerated it. Ironically, flood-protection levees are one of the chief man-made causes of subsidence. When the corps started systematically leveeing the river in the 19th century, it cut off the region's main source of silt, the raw material of delta-building. The weight of large buildings and infrastructure and the leaching of water, oil and gas from beneath the surface across the region have also contributed to the problem.

The Mississippi River delta is subsiding faster than any other place in the nation. And while the land is sinking, sea level has been rising. In the past 100 years, land subsidence and sea-level rise have added several feet to all storm surges. That extra height puts affected areas under deeper water; it also means flooding from weaker storms and from the outer edges of powerful storms spreads over wider areas.

The marshes that ring New Orleans have sunk the quickest. "We live on a platform given us by the Mississippi River," Curole said. "But Yscloskey, New Orleans, all the way to western Terrebonne Parish, we're all in the same boat, and it's sinking." The combination of sinking land and rising sea level has put the Mississippi River delta on average 2 feet lower relative to sea level than it was 60 years ago, according to studies by University of New Orleans geologists. According to data that UNO researchers gathered for The Times-Picayune, the marshes around Bayou Teche are more than 2 feet, 9 inches lower than they were in 1942. At Schooner Bayou to the west, the figure is more than 1 foot, 4 inches. The New Orleans lakefront has been comparatively lucky, sinking 5 inches in that time.

WASHING AWAY

WATER ALL AROUND



RIDING HIGH • The Mississippi River is currently about 15 feet above sea level, or about 2 to 5 feet above ground in the French Quarter and Algiers Point. Here, a cargo ship towers high above the river, its deck more than 120 feet above the water.

ROOFTOP LEVEL •

A 17 ½-foot levee is all that separates lavish homes, such as this one between Marconi and Wisner boulevards, from Lake Pontchartrain. Just beyond the levee, street level is about 6 feet below the surface of the lake.



By 2100 the area will be an additional 3.2 feet below sea level, according to a paper analyzing future trends in sea-level rise and subsidence by scientists at the U.S. Geological Survey, the National Geodetic Survey and other agencies. Most of the region's original settlements were built on a network of ridges that were relatively safe from flooding. Now they're going under. "Areas near Shell Beach (in St. Bernard Parish) that didn't flood during (Category 5 Hurricane) Camille did flood during (Category 2 Hurricane) Georges," said University of New Orleans geologist Shea Penland. "The ridges had subsided, trees had died because of saltwater intrusion, and the wetlands are converting from a brackish marsh system to a fragmented salt marsh." The owners of Campo Marina at Shell Beach have raised the dock and marina shed a total of 3 feet since it opened in 1960. "Water started coming over the steps, so we raised it. Ten years later it came over the steps again and we raised it. And it still comes up," owner Ken Campo said.

Models predict dire floods, erosion

Computer modeling shows how the threat of flooding has spread and deepened across a wide area. Using digitized maps of the delta landscape from the 1800s up to a projected map for 2020, Louisiana State University engineers Joseph Suhayda and Vibhas Aravamuthan showed how flooding from a hypothetical storm got deeper and spread steadily westward and northward as erosion and subsidence took their toll. Houma, dry in a 1930 simulation of a Category 3 hurricane, would be surrounded by water in the same storm in 2020. At the same time,

flood levels are lower along the coast because there is no longer anything to block the water and cause it to build up; it all flows inland. As the Mississippi delta sinks, the coastline grows ragged. Saltwater flows farther inland and kills sensitive plants that hold the marshes together. Human activities — such as canal-building, drilling and dredging — have sped up the fragmentation of marshes and worn down barrier islands. Erosion has created a distinct set of problems. Unlike subsidence, erosion doesn't make flooding much deeper or worsen direct hits by major storms. But it has amplified the weaker storms and glancing blows by stronger ones because there is less

marsh to slow the floodwaters and wind. Storms in turn tear up marshes and islands and accelerate the cycle of decay. Marshes are a rough surface that produces drag on moving masses of water and wind, causing a storm-surge wave to lose energy and height and the wind to die down as they move inland. As the marsh disappears, so does the benefit. Scientists working for the state Department of Natural Resources measured some of these effects during Hurricane Andrew in 1992. Andrew's surge height dropped from 9.3 feet at Cocodrie to 3.3 feet at the Houma Navigation Canal 23 miles to the north. For every mile of the

marsh-and-water landscape it traversed, it lost 3.1 inches of height, sparing some homes farther north from more flooding. Barrier islands are low-lying, eroding outcroppings of delta, but their role in storm surges looms large. Every extra mile of barrier beach and each vertical inch keeps some water from flowing inland during a storm. Even small changes in the islands' shape change the speed and height of storm surges, tides and wave action behind them. LSU scientist Suhayda has done computer modeling that shows that if barrier islands had not been there during Hurricane Andrew, then Cocodrie would have seen an extra



LAST ISLAND'S

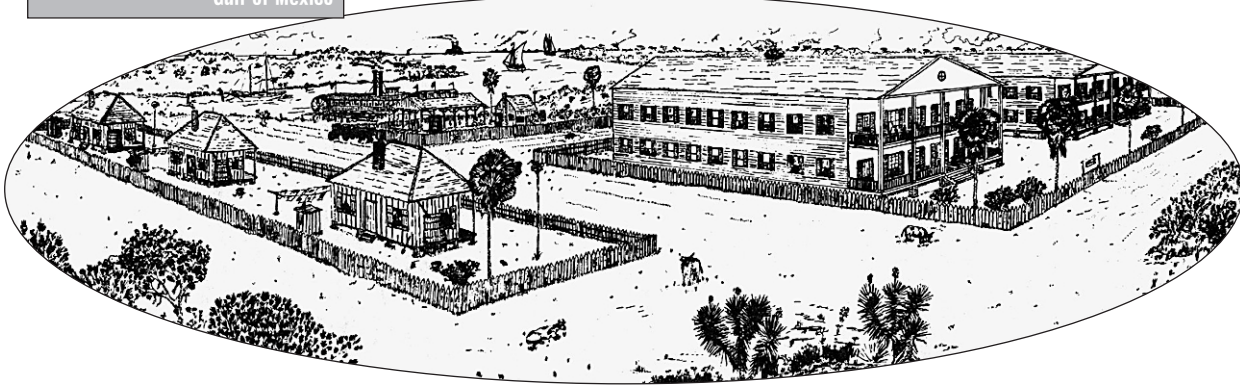


ILLUSTRATION JAMES M. SOTHERN, FROM HIS BOOK 'LAST ISLAND'

When the regularly scheduled steamer failed to arrive, vacationers realized they were trapped and that the Gulf would soon sweep over the island. 'The wind blew a perfect hurricane; every building upon the island giving way, one after another, until nothing remained. ... Men, women and children were seen running in every direction, in search of some means of salvation,' according to a Mr. Duperier, an eyewitness quoted in the Aug. 14, 1856, Daily Picayune.

WASHING AWAY

US *With most of New Orleans below sea level, levees offer the only defense from catastrophic flooding. But even with levees, the potential for disaster is clear. If one were to break or be topped, the defenders would suddenly become the enemies, trapping water and allowing it to fill New Orleans.*



BARRIER LINES •
A floodwall divides Orleans Avenue from the Orleans Avenue Outfall Canal, one of the many drainage canals that channel storm water into Lake Pontchartrain. In a catastrophic storm, the lake would back up into the canals, giving the floodwaters a beeline straight into the heart of the city.



STAFF PHOTOS BY ELLIS LUCIA

LAKE VIEWS • Along with the river, the 630-square-mile Lake Pontchartrain dominates the landscape of New Orleans. In the event of a hurricane, it also presents the dominant danger. Some hurricane experts fear that even a moderate hurricane could churn up the lake, causing a sloshing effect that would top the levee, leaving much of New Orleans under water, possibly for months. If the levee were topped, houses such as these near Lakeshore Drive between Canal and Wisner boulevards could be completely underwater.

foot of water. If island heights were raised and inlet channels between them narrowed, the surge hitting Cocodrie would have been cut by as much as 4 to 5 feet.

The widening areas of open water across south Louisiana may even allow storms to retain more strength as they move inland, said Hugh Willoughby, director of NOAA's Hurricane Research Division in Miami, though scientists have not yet closely examined the issue.

One example of this phenomenon may have been Hurricane Danny, which made landfall at Grand Isle in 1995. "Hurricane Danny was a tropical storm over Grand Isle and then it intensified," said Curole of the

Lafourche levee district. "You can't find a record of any storm or hurricane before that that intensified after it crossed a barrier island."

'We're still recovering'

The emerging new landscape of open water and levees ringing cities and towns is in some ways more dangerous than the old.

The risks vary dramatically depending on where you live. Communities outside federally built hurricane levees — which protect New Orleans, East Jefferson and parts of St. Bernard, the West Bank and Lafourche Parish — have little protection from storm surges, depending mostly on smaller levees likely to be

topped.

Hurricanes have frayed these communities over the years. Many residents — mainly younger people — have moved north. In Dulac, every other block contains businesses that never reopened after Hurricane Andrew pushed a 10-foot flood through town in 1992: a shrimper's supply store, a branch office of the energy exploration company Unocal, Dwayne's barber shop.

On Orange Street, damaged homes and trailers sit shuttered, waiting for the next flood to claim them. "We're still recovering," resident Donald Lirette said. "These houses are rotting because of water, abandoned now. They turn them into crackhouses."

Inside levees, the threat is different.

If enough water from Lake Pontchartrain topped the levee system along its south shore, the result would be apocalyptic. Vast areas would be submerged for days or weeks until engineers dynamited the levees to let the water escape. Some places on the east bank of Orleans and Jefferson parishes are as low as 10 feet below sea level. Adding a 20-foot storm surge from a Category 4 or 5 storm would mean 30 feet of standing water.

Whoever remained in the city would be at grave risk. According to the American Red Cross, a likely death toll would be between 25,000 and 100,000 people, dwarfing esti-

mated death tolls for other natural disasters and all but the most nightmarish potential terrorist attacks. Tens of thousands more would be stranded on rooftops and high ground, awaiting rescue that could take days or longer. They would face thirst, hunger and exposure to toxic chemicals.

"We don't know where the pipelines are, and you have the landfills, oil and gas facilities, abandoned brine pits, hardware stores, gas stations, the chemicals in our houses," said Ivor van Heerden, assistant director of the LSU Hurricane Center. "We have no idea what people will be exposed to. You're looking at the proverbial witch's brew of chemicals."

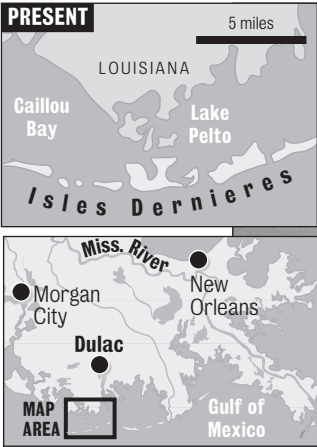
Scientists address the risk

These complex dangers have inspired some to come up with audacious plans to avert disaster. LSU scientist Suhayda, for example, proposes bisecting New Orleans and Jefferson Parish from east to west with a flood wall rising 30 feet above sea level starting at the foot of Esplanade Avenue, running toward Lake Pontchartrain and then across the city along the Interstate 610 corridor into Metairie. That would create a "community haven" on the river side of the wall where those left behind could retreat, and would protect buildings from floodwaters entering from the lake.

Only in the past few years have government agencies and political and community leaders mobilized to address rising storm risks from the sinking coast and the potential catastrophe in the New Orleans area. The Federal Emergency Management Agency is preparing a plan for the unprecedented response that would be needed if the New Orleans bowl

WALTZ

A few years before the Civil War, one of the most legendary storms to strike the Louisiana coast destroyed Last Island. Each summer, wealthy New Orleanians would take the steamer down to the resort. On Aug. 9, 1856, as hotel guests waltzed away the night, gale winds began whipping outside. The next morning, the guests awoke to a hellish fury.



STAFF PHOTOS BY ELLIS LUCIA

The 1856 hurricane claimed at least 200 lives on Last Island, today a series of islets known by the French name Isles Dernieres. 'At about 4 o'clock, the Bay and Gulf currents met and the seas washed over the whole island. ... No words could depict the awful scene,' The Daily Picayune wrote after the storm.

WASHING AWAY

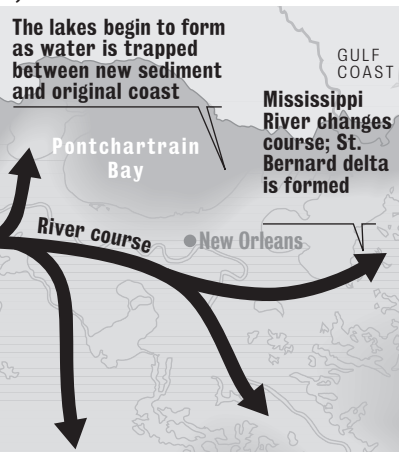
For millennia, the Mississippi's silt-rich floodwaters built up the land. But man cut off the river from Louisiana's marshlands. Then he attacked the marsh itself, crisscrossing it with canals and pipelines. The result: The land is sinking, the Gulf is creeping closer, and the natural barriers to a hurricane are disappearing.

NATURE, INTERRUPTED

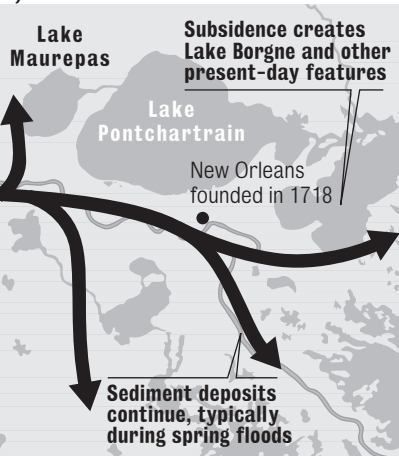
5,000 YEARS AGO



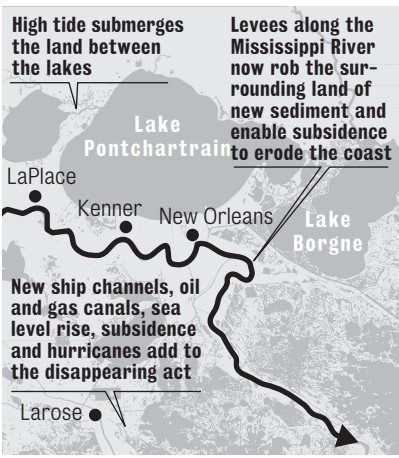
4,000 YEARS AGO



2,000-200 YEARS AGO



PRESENT DAY



2050-2100



Sources: U.S. Geological Survey, Army Corps of Engineers, staff research

STAFF GRAPHIC BY DANIEL SWENSON



STAFF PHOTO BY ELLIS LUCIA

SALTWATER INTRUSION • The destruction initiated by man is perhaps best illustrated by the dying swamps that dominate many parts of south Louisiana. After river levees stopped the flow of fresh water to marshes, erosion and subsidence allowed saltwater to intrude. Soon, no vegetation can live, and nothing remains to hold the marsh together. Eventually, the area is the open Gulf.



STAFF FILE PHOTO BY JOHN MCCUSKER

NUTRIA • The marshes and levees are also under attack from a committed four-legged foe: the nutria. The creatures were imported into Louisiana for their fur, but after a few escaped into the wild they quickly established themselves. By burrowing, the animals seriously weaken levees.

PIPELINES • Oil pipelines coated in concrete, left, were buried throughout south Louisiana. But today, many lie exposed in marshes where once-solid land has eroded around them.



STAFF PHOTO BY ELLIS LUCIA

CANALS • For centuries, countryside and marshland throughout Louisiana were carved up to create a series of canals that criss-cross the state for trapping, fishing, oyster farming or oil exploration. But the canals accelerated the natural erosion process, and today it's hard to tell where the canals end and where marshland or Gulf waters begin.

Sinking
turf, rising
seas spell
disaster

HURRICANE, from Page 5

were flooded. The corps has begun a study to look at whether the levees surrounding the New Orleans area should be raised high enough to prevent that scenario. Local scientists, politicians and some business leaders have forged a consensus that the region's best shot for long-term survival is a major effort to rebuild lost marshes and barrier

islands. But it would cost at least \$14 billion. The region remains on a precipice. The lucky record of near misses could continue — or run out. Between 1909 to 1926, for example, three major hurricanes and two smaller storms hit south Louisiana. A series of smaller storms over a few seasons could devastate many towns. A single major storm could cripple New Orleans. “A legitimate question to ask is:

Given this kind of catastrophe, given the city is on its knees, many of its historic structures have been destroyed, considering the massive influx of federal dollars that will be required, do you rebuild it?” said Walter Maestri, Jefferson Parish emergency services director. “I don’t know the answer to that. Especially since we’re below sea level and it can happen again the next week. “That’s a question for the elected political leaders I work for,”

he said, recalling the founding of New Orleans in 1718 by Jean Baptiste le Moyne, sieur de Bienville. “Planners need to think about that: Do we repeat Bienville’s mistake?”

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WASHING AWAY



Albert 'White Buffalo' Naquin visits a gravesite near the area of his birth, Isle de Jean Charles. The burial ground, like the community itself, is sinking into the marsh.

Written off

The Gulf is slowly swallowing Isle de Jean Charles and other south Louisiana towns. A new federal levee promises to save some but leaves others exposed to the elements that eventually will wipe them from the map.

For the government, it's a question of cost vs. benefit. For residents, it's a question of survival.



STAFF PHOTOS BY ELLIS LUCIA

A tiny sliver of land is all that's left to tie Isle de Jean Charles to the rest of civilization. The road was paved in the 1970s, and in the 1990s was raised by 4 feet.

By John McQuaid
Staff writer

ISLE DE JEAN CHARLES

THE road to the island is a narrow strip that runs two miles across open water, buttressed on both flanks with hewn granite boulders. Broad savannas of marsh around it have withered and dissolved, and dead cypresses reach up out of the shallows like monstrous claws. In a high tide, water laps close to the asphalt. In a storm, the road disappears.

The road is the one physical link to the rest of America for Isle de Jean Charles and its community of Biloxi-Chitimacha-Choctaw Indians, whose ancestors settled the wilderness of what is now Terrebonne Parish in the early 1800s. The first settlers may have come to "hide from the white folks that wanted to kill 'em," said Chief Albert Naquin. Or, according to one legend, to stash some of Jean Lafitte's pirate treasure.

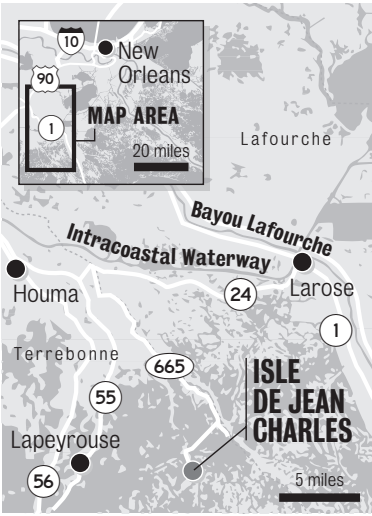
Naquin has made the road into something of a personal crusade. He saw it built 50 years ago when he was a small child and the first trucks and cars made their way onto the island via a rutted dirt

track across the marsh. He saw it inlaid with crushed clamshells by the 1960s and blacktopped in the 1970s. He wheedled bureaucrats to get it raised by 4 feet and reinforced in the 1990s.

But now Naquin's efforts to keep the island's lifeline open may turn out to have been for nothing. America — or at least the federal government — is giving up on Isle de Jean Charles. The community, along with others near the coast, will be left outside of a major federal levee project — something many residents saw as the island's last shot at long-term survival in the face of strong hurricanes.

All of the island's structures and 240 souls could be washed away by a hurricane or even a tropical storm, and its situation is worsening because of the slow, relentless onslaught of salt water from the Gulf of Mexico.

Technically speaking, it's not even an island, but a ridge rising a few feet above the marshes, 23 miles inland from Timbalier Island on the coast. But it soon will be. Water encroaches from all four points on the compass. Parts of the island road, which connects to Pointe-aux-Chenes and solid land, have already sunk 6 inches in the two years since workers finished



STAFF MAP

raising and fortifying it.

All of the island's structures and its souls could be washed away by a hurricane or even a tropical storm. Its predicament recalls how hurricanes have helped shape the history of south Louisiana, sometimes wiping out entire towns, sometimes forcing people to pick up and leave.

In 1893, for example, a hurricane obliterated the tiny Cheniere Caminada settlement near Grand Isle, killing at least half the 1,600 inhabitants. Many were buried in a mass grave that still sits next to Louisiana 1. Hundreds of Cheniere

Caminada survivors moved north to Leeville. But in 1915, another hurricane destroyed Leeville, killing dozens of people and wrecking 99 of 100 buildings.

Levee offers ray of hope

With coastal erosion and subsidence, many bayou communities are worse off now than they were a century ago. The Army Corps of Engineers has a solution for some of them: a proposed 14-foot-high hurricane levee that would snake eastward for 72 miles from Bayou Black outside of Houma, enclosing towns including Dulac, Lapeyrouse and Montegut before finally connecting to the existing hurricane levee at Larose.

But some places would be left outside the levee because corps engineers have determined it would cost too much to build the barrier around them. Cocodrie is out of luck, as are half of the homes and businesses along Bayou du Large. So is Isle de Jean Charles.

"The politicians all know about this, but it hasn't done us much good. Not much money comes from this place," said lifelong resident Lonney Dardar, 78. "But just leaving it open for a hurricane, it's not what God would do for his people. This island would be drowned."

As coastal erosion, subsidence and sea-level rise bring higher waters farther inland each year, all of south Louisiana will become ever more dependent on the federal government for more spending for protection that is less and less effective. At some point, local officials fear, the cost-benefit analysis can turn against anyone.

The corps could theoretically build a 30-foot-high wall that encloses all of south Louisiana, shielding it from the highest imaginable hurricane storm surges. But levee building is not just an engineering feat, it's a political process. Congress would never approve such a gigantic project: It would cost tens of billions of dollars, cause ecological problems and drive maintenance costs into the stratosphere. So the agency has to choose how much levee protection to offer and whom it can protect.

Communities left out must gamble on small, locally financed levee systems that can buy them relief from tidal flooding but not hurricanes. Many of them face a slow death over the decades, or a quick and violent end at some point in the future. Hurricanes will likely pull the curtain down on hundreds of years of history and memories of

GOING UNDER

REVISITING BETSY

Betsy was one of three direct hits on the New Orleans area in the past 100 years. Almost a Category 5 storm when it sped ashore at Grand Isle, Betsy had weakened to a Category 3 an hour later when its eye was 35 miles southwest of New Orleans, battering the city with 125 mph winds. A storm surge ranging from 8 to 16 feet flooded more than 5,000 square miles of the coast, topping 8-foot levees in Chalmette, along the Mississippi River-Gulf Outlet in eastern New Orleans, and at Camp Leroy Johnson on Lake Pontchartrain. The surge also pushed through a siphon underneath a levee along the Inner Harbor Navigation Canal, flooding the 9th Ward.



THE DAMAGE

Damage was widespread in St. Bernard Parish, eastern New Orleans and the 9th Ward, and 58 people lost their lives in Louisiana. Many drowned in their attics, where they attempted to escape floodwaters that rose 20 feet in some places in 15 minutes. About 17,600 people were injured and 250,000 evacuated. Some buildings washed off their foundations, were carried 10 miles by surge water and ended up against levees or in the middle of intersections. Several ships ran aground on the Mississippi River levees.



After Betsy left much of the 9th Ward under water, volunteers ferried people stranded on rooftops to high ground, such as the bridge over the Industrial Canal. STAFF FILE PHOTO BY G.E. ARNOLD

THE SOLUTION

Reinforced by public opinion resulting from Betsy, the Army Corps of Engineers gained congressional financing for a series of flood-control and levee-building projects that were already under way to protect the New Orleans area from storms similar to hurricanes that hit the city in 1915 and 1947.



The Army Corps of Engineers began building the first concrete floodwalls along the east bank of the Inner Harbor Navigation Canal, such as here between Hayne Boulevard and Dwyer Road, in 1968. STAFF FILE PHOTO

BUT ARE WE REALLY SAFE? ...

WASHING AWAY

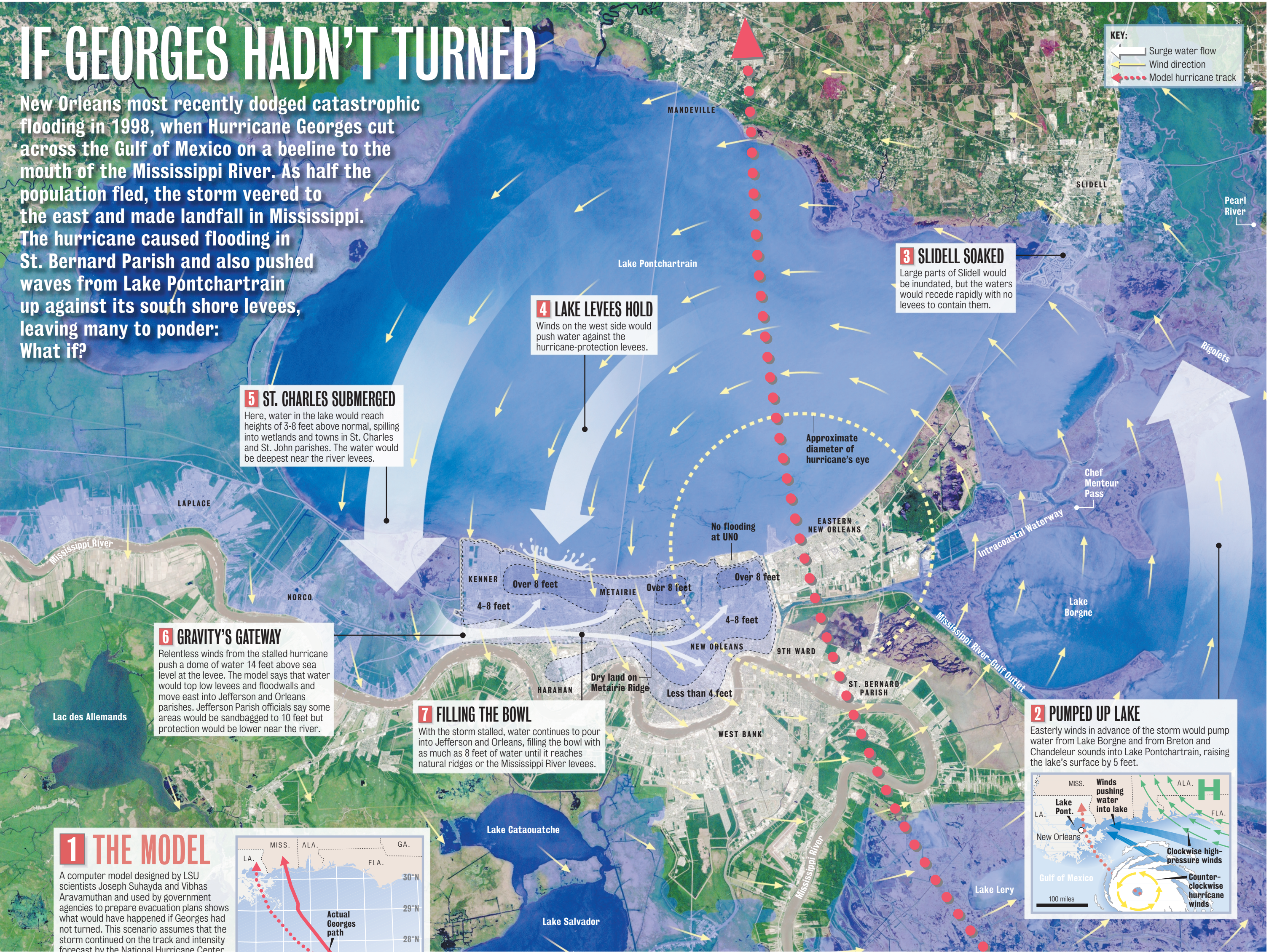
Hurricane Betsy flooded New Orleans with attic-high water in 1965, accelerating a massive public works effort to protect the area from storm surge and flooding. But advances in computer modeling show that dangerous weak spots in the levees could result in a catastrophic flood. Erosion and subsidence make south Louisiana all the more vulnerable to hurricanes.

Staff graphic by Daniel Swenson/dswenson@timespicayune.com

IF GEORGES HADN'T TURNED

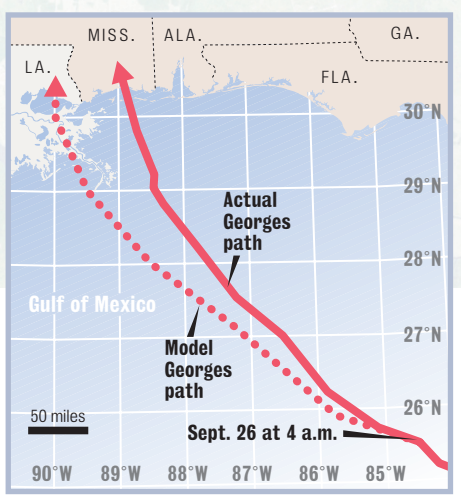
New Orleans most recently dodged catastrophic flooding in 1998, when Hurricane Georges cut across the Gulf of Mexico on a beeline to the mouth of the Mississippi River. As half the population fled, the storm veered to the east and made landfall in Mississippi.

The hurricane caused flooding in St. Bernard Parish and also pushed waves from Lake Pontchartrain up against its south shore levees, leaving many to ponder: What if?



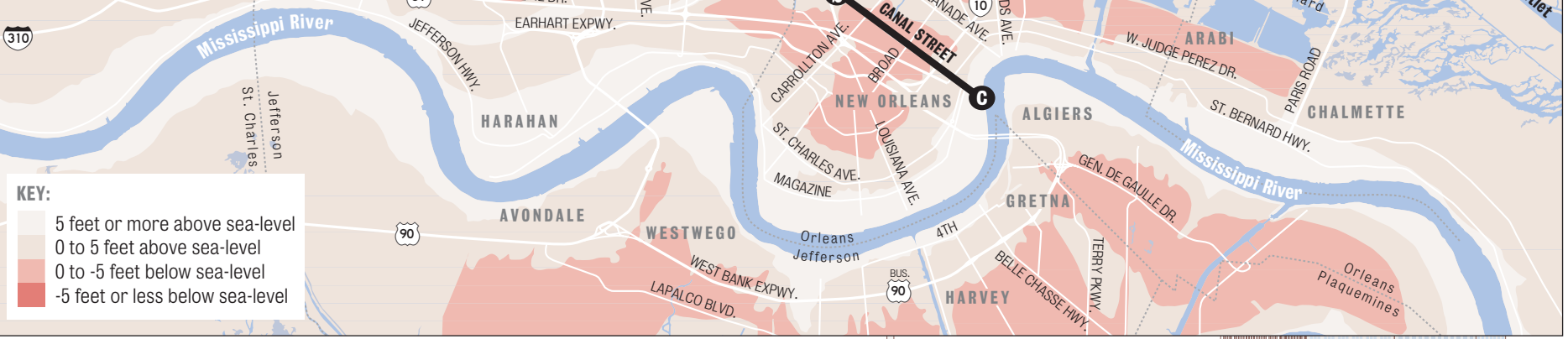
1 THE MODEL

A computer model designed by LSU scientists Joseph Suhayda and Vibhas Aravamuthan and used by government agencies to prepare evacuation plans shows what would have happened if Georges had not turned. This scenario assumes that the storm continued on the track and intensity forecast by the National Hurricane Center on Saturday, Sept. 26, 1998, at 4 a.m. In the model, Georges intensifies to a Category 3 with 115-mph winds when it makes landfall just west of the mouth of the Mississippi. During the next two days, it moves slowly northwest, weakening to a Category 1 and stalling over eastern New Orleans. Here's what would happen ...



EXPLAINING THE BOWL

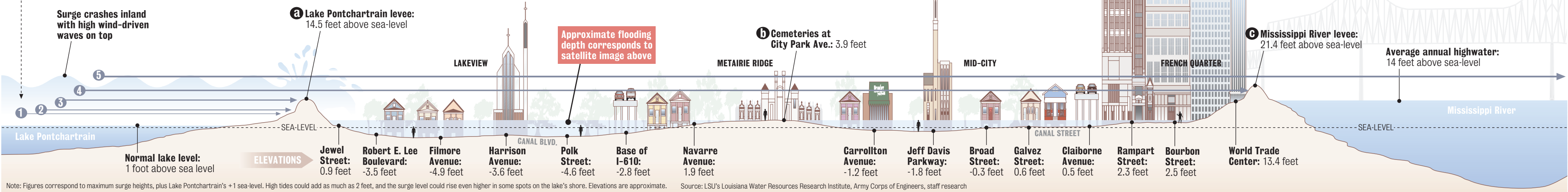
Much of the area is below sea-level, creating a natural "bowl." Storm surge simply follows the law of gravity and meanders to the lowest points.



CITY BELOW THE SEA

When a hurricane even stronger than Georges hits New Orleans, Lake Pontchartrain — a foot higher than sea level — will be the city's biggest threat. Surge water from the Gulf of Mexico, topped by towering waves, will swell the lake above levees and cause widespread flooding. A look at average surge levels by category, compared to a cross-section of the city known as "the bowl":

Hurricane Category	Surge and waves at low tide*	Effect on New Orleans
1	7 feet	Lake Pontchartrain's levees stop the low-level surge
2	9 feet	Levees stop the surge, but some waves could find their way over
3	14 feet	Levees stop bulk of surge, but waves could cause considerable flooding
4	19 feet	Levees topped, causing catastrophic flooding
5	24 feet	Entire city submerged including Mississippi River levees



Note: Figures correspond to maximum surge heights, plus Lake Pontchartrain's +1 sea-level. High tides could add as much as 2 feet, and the surge level could rise even higher in some spots on the lake's shore. Elevations are approximate.

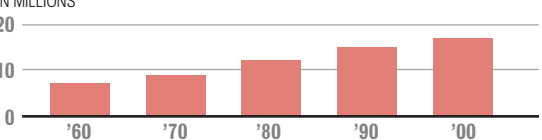
Source: LSU's Louisiana Water Resources Research Institute, Army Corps of Engineers, staff research

WHY IS OUR COAST MORE VULNERABLE?

EXPANSION AND DEVELOPMENT

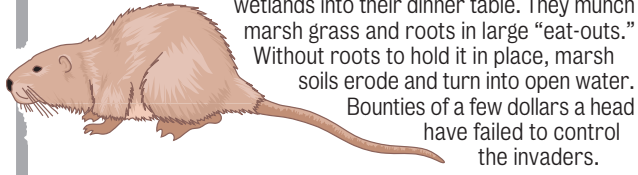
Metairie, Kenner and Mandeville are examples of rapid population growth along the state's coastline. Today, twice as many people and structures are in harm's way than there were 40 years ago.

Coastal population of the Gulf of Mexico:



FOREIGN INVADERS

Nutria are large, beaver-like rodents imported from Argentina for the fur trade at the beginning of the 20th century. With few natural enemies, they turned Louisiana's wetlands into their dinner table. They munch marsh grass and roots in large "eat-outs." Without roots to hold it in place, marsh soils erode and turn into open water. Bounties of a few dollars a head have failed to control the invaders.



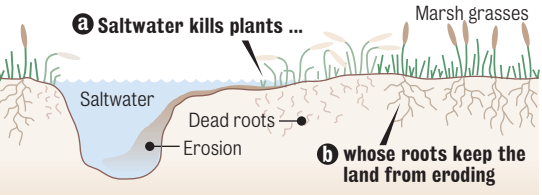
CANALS/CHANNELS

Thousands of miles of weblike pipeline and navigation canals have destroyed some marshes and cut off others from natural water flow, opening them up to saltwater intrusion and erosion by boat traffic. Louisiana loses an acre of land from all causes, equivalent in size to three football fields, every 24 minutes.



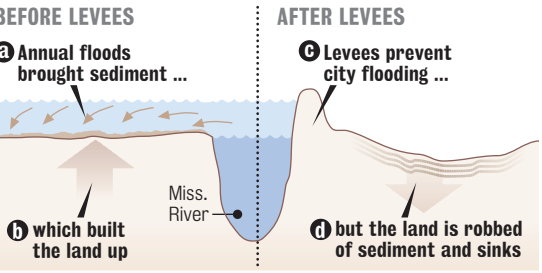
SALTWATER INTRUSION

Saltwater from the Gulf moves inland through canals and waterways such as the Mississippi River-Gulf Outlet, killing freshwater plants that can't stand the salt. As the plants die, the soil their roots hold together is eroded away.



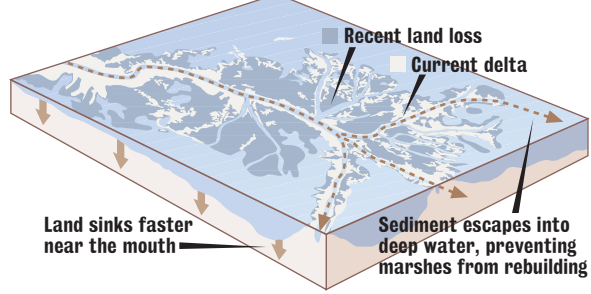
LEVEES

The Mississippi River's springtime floods plagued New Orleans for two centuries until levees protected the city and created stable channels for shipping. But the levees also cut off the sediment-rich floodwaters that built the land on which the city sits, and that kept alive the coastal marshes that help protect the city from hurricanes.



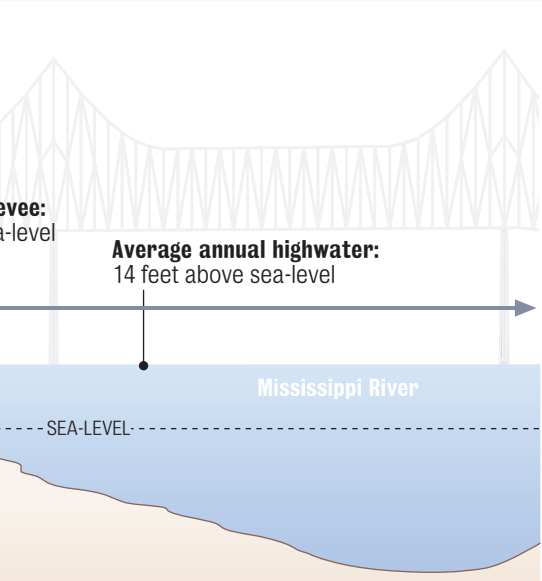
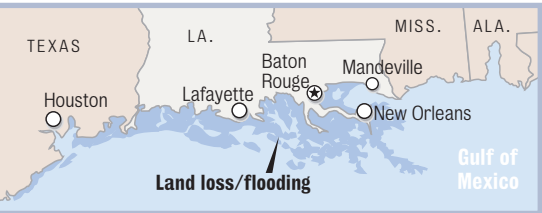
SUBSIDENCE

Soft sediment beneath Louisiana's coast is sinking, as water and gases are squeezed out by the soil's own weight and new sediment fails to replenish the loss. In New Orleans, already 6 feet below sea-level, land is sinking an average of an inch every three years. At the mouth of the Mississippi, land is sinking as quickly as 4 feet every 100 years.



SEA-LEVEL RISE

Scientists say global warming is adding to existing sea-level rise and subsidence, and the Gulf of Mexico could rise by as much as 3 feet along Louisiana's coast in 100 years. At high tide and without coastal restoration, the following areas could flood:



WASHING AWAY

STORM REMINDERS

According to lore, Cheniere Caminada's chapel bell began pealing on its own as an unexpected and devastating hurricane blew ashore on Oct. 1, 1893. The town's priest, Father Ferdinand Grimaud, was long remembered for his heroism, gathering up parishioners and urging them to safety. More than half of the resort and fishing village's 1,600 residents were killed in the storm. After the storm many survivors moved farther inland.



CHENIERE HURRICANE CENTENNIAL

THEN • More than 800 people died in Cheniere Caminada near Grand Isle during the unnamed hurricane of 1893. Many of the victims were buried in Lady of Lourdes cemetery along what would become Louisiana 1 in a mass grave, seen in this photo thought to have been taken shortly after the tragedy. The island and the storm would later form the basis for the novel 'The Awakening' by Kate Chopin, who often visited the resort.



STAFF PHOTOS BY ELLIS LUCIA

TODAY • Graveyards, many holding victims of the 1893 hurricane that wiped out the tiny Cheniere Caminada settlement near Grand Isle, are slowly disappearing into the swamp. Even as the swamp devours everything in its path, new housing emerges in the distance, beyond a graveyard along Louisiana Highway 1 that is slowly disappearing. Over the years, the erosion has accelerated as saltwater intrudes and kills oaks and other vegetation. Without the trees and vegetation, there's nothing to hold the earth together.



Exclusion from levee will drown history

ISLAND, from Page 7

place, lives lived, marriages forged, births, divorces, deaths.

"The value of the island, you don't see it at first," said Thomas Naquin, Albert's father-in-law and a Terrebonne levee commissioner. "There is heritage. There is sentimental value. There is a burial ground down there with the ancestors. Are they just going to let them get washed away?"

In the early 1800s, a multiethnic mix of French, Cajun, Spanish and Indian people lived along the bayous of south Louisiana, including bands of Houma, Biloxi, Choctaw and Chitimacha Indians. Some intermarriage occurred, especially among European men and Indian woman, so most of the Indians today are of mixed ancestry.

The Indians, in that era formally represented by the Houma tribe, lost out on a bid to have the federal government hold lands in trust, so no

reservation exists today, something that might have given Isle de Jean Charles the political clout to be included inside the levee.

The island was officially considered to be "uninhabitable swamp land" until 1876, when property records show the first plots were sold to Jean Baptiste Narcisse Naquin and three others, all related by marriage. Naquin opened a store on the upper part of the ridge to the north, where the road enters the island today. The Choctaw Indian is said to be the first chief of the island.

"The chief had the grocery store, was responsible for the mails, arbitrated disputes, represented the people of the island with outsiders, and gathered the residents for group work in the community," the tribal history reads. "Each chief named his successor, being the person he thought best qualified to fulfill the duties; the position was not inherited by birth nor has it ever been challenged by persons of the community." Albert Naquin's brother Deme passed the title to him in 1997.

Nature nurtures settlers

The settlers dug what is now Bayou Jean Charles with shovels and buckets. They built houses on either side of the bayou and engineered home-made bridges. A local culture emerged with its own rhythms and traditions. Until the early 1900s, residents lived in houses with walls made

of "bousillage," a clay-mud mixture, with dome-shape roofs covered with palmetto. At the crown was a smoke hole that could be closed when it rained.

Like other bayou dwellers, islanders lived off the marshes, catching crawfish and shrimp, oystering and trapping muskrats. Until about 30 years ago, residents say, the island had enough land for farming.

"We had woods all the way to the back, a quarter mile or more, and we'd chop trees during the summertime to dry so that during the winter we'd have wood for cooking and heating," said the Rev. Roch Naquin, Albert's first cousin. "We used to have farming. Gov. Sam Jones (who was in office from 1940 to 1944) provided people with mules or horses and plows and know-how. They used to plow all across the bayou: potatoes, beans, corn, butter beans, okra, melons."

But that land has disappeared, and saltwater pervades what used to be a brackish marsh, making planting impossible. No space remains for the horses, cattle and pigs that once roamed the island's expansive back lots. Several causes are to blame for the accelerated erosion, among them the construction of a canal for oil and gas service vessels and several pipelines that route around the island.

Across the bayou, Albert Naquin's sister Denecia and her husband, Wenceslaus Billiot, have watched the

steady progress of water encroaching toward their back yard, where Billiot carves and assembles model shrimp boats complete with miniature rigging in a work shed. "The last 20 years, it's been real bad. We used to hang our clothes and cut the grass all the way back there, a hundred yards out," he said. "Today, the water is right over the fence."

Albert Naquin's childhood home, built in the 1920s, used to stand at the south end of the road. Naquin was one of 12 children, six of whom survive today. When he was growing up, he said, the children slept two or three to a bed. An outhouse and a chicken coop sat in the back yard, a dock with a shrimp boat and pirogue in the front. Today, all that remains is the dock.

"In '65, Betsy tore it up," Naquin said. "It tore the side off and the roof. Inside it got all wet, so we decided to move out and build us a new one a half mile up the road."

Floods drive away residents

The island was spared the catastrophes that struck other places in the 19th and early 20th centuries. But in the past 40 years, many longtime residents say, they have been hit repeatedly by storm-surge flooding.

"Four times I had water in my house," said Michel Dardar, 75, who lives on the east side of the bayou in a house on 4-foot pilings. "There was Hurricane Hilda in '64. We had water up to here, about 36 inches. In '74

there was Carmen. That put 38 inches in the house. Hurricane Juan (in 1985), 18 inches. With Andrew (in 1992), 18 inches. In the first two hurricanes, the house was lower. After Danny (in 1985) I raised it. But it didn't solve the problem."

They used to stay and ride out storms. The Billiot's recall the winds from Betsy shaking their rafters. Now, with the danger greater, everybody leaves, with the exception of one or two die-hards.

"We have come to realize, even before they say evacuate, we're gone," said Chris Brunet, 36. "Because we live in a low-lying area, nobody wants to be trapped. In Hurricane Juan the water was coming up so fast people had to follow the (lights) of the vehicle in front of them because they couldn't see the edges of the road."

Once tightknit, the community is now fragmenting and in decline like the marshes around it. Today many residents barely make a living. Some are on public assistance. The average age has been creeping upward as young people leave. Jobs and the appeal of urban or suburban life have drawn many away.

Flooding has driven others out. At times, even with smaller storms, the road is impassable, so commuting is dicey. Even Albert Naquin, now retired from his job as an inspector for the Minerals Management Service, moved his family to Pointe-aux-Chenes in the 1970s.

So island residents greeted the

WASHING AWAY

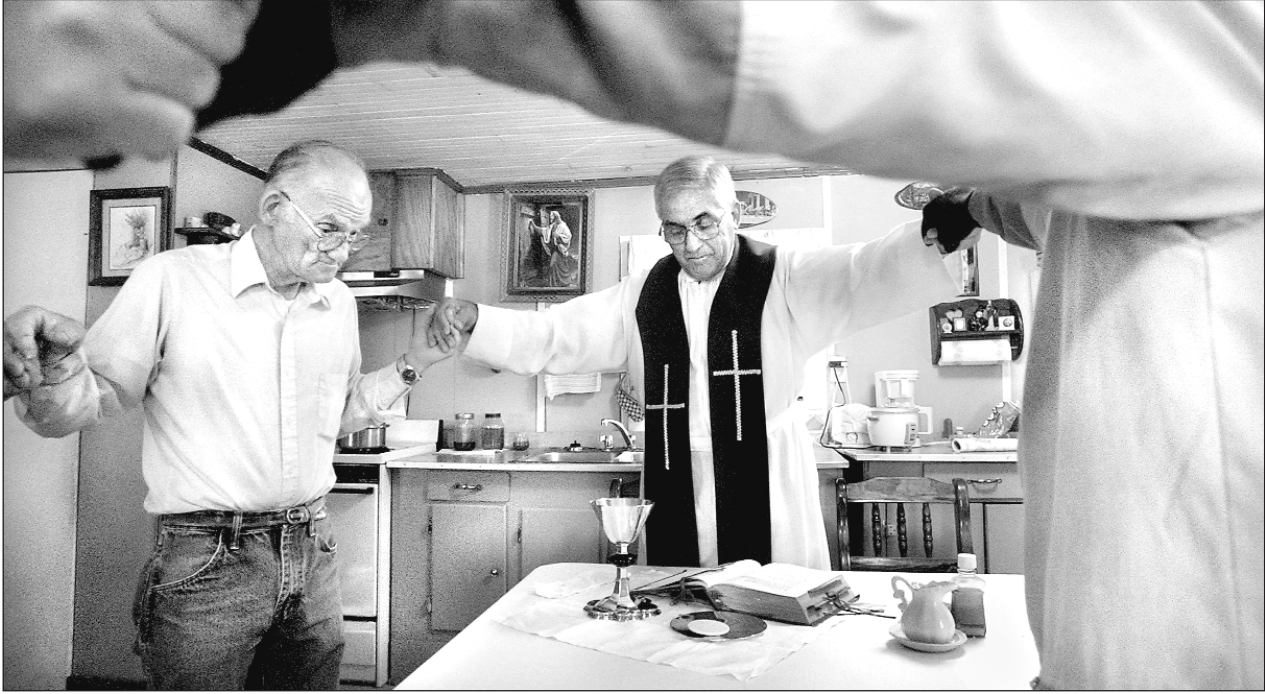
“Just leaving (this community) open for a hurricane, it’s not what God would do for his people. This island would be drowned.”

LONNEY DARDAR, a lifelong resident of Isle de Jean Charles



STAFF PHOTOS BY ELLIS LUCIA

The long-term prospects for Isle de Jean Charles plummeted when the Army Corps of Engineers opted not to include the island in a federal levee project.



The Rev. Roch Naquin says Mass at the home of his neighbor, Michel Dardar, left, with Albert Naquin and Bridgette Brunet on Isle de Jean Charles. There are no Catholic churches on the island, a remote American Indian community in Terrebonne Parish.



Wenceslaus Billiot and his wife, Denecia, have watched as their land slowly has become one with the swamp. ‘We used to hang our clothes and cut the grass all the way back there, a hundred yards out,’ he said. ‘Today, the water is right over the fence.’

prospect of a levee with relief, an engineering solution that could save their home or at least give it a chance at long-term survival. For example, Naquin says the island’s vulnerability to floods makes it almost impossible to get state and federal money to build public projects.

Designing and building a hurricane levee is a long process involving generations of studies on all possible impacts — environmental, cultural and economic — and different levee configurations. Several preliminary designs included Isle de Jean Charles inside the proposed project, called the Morganza-to-the-Gulf levee, which is designed to protect against a flood from a fast-moving Category 3 hurricane.

But the draft proposal for the levee, released late last year, left the community outside. The proposal calls for the levee to cut to the north and west of the island.

The corps estimated that levee protection would be worth \$900,000 a year to Isle de Jean Charles. According to the agency’s cost-benefit formula, that would justify spending \$13 million on it. But running the levee southward into open marshes would, according to the study, add \$190 million to the \$680 million estimated cost, 28 percent. The report concluded that the economically optimal thing to do would be to move the community elsewhere for a relatively cheap \$8 million.

Decision recalls ‘Trail of Tears’

Albert Naquin and many of the islanders reject the Corps’s conclusions.

“For us as a Native American community to be left without protection, (exposed to storms) that could wash away our very lives, would constitute a modern-day version of the Trail of Tears,” Naquin wrote in a letter to the corps recalling the 1838-39 removal and forced march of the Cherokee Indians from their tribal lands in the eastern United States to what is now Oklahoma.

But with the levee proposal complete, it’s unlikely any major changes will be included. Even the Houma Courier newspaper, which has been sympathetic to the plight of Isle de Jean Charles, recently editorialized against including it.

“It’s understandable that island residents don’t want to abandon their heritage and their land — no one wants to see the death of a culture,” the editorial said. “But their departure seems inevitable. Mother Nature is reversing the course of man: Man built the road connecting the island to the mainland; Mother Nature is washing it — and the entire island — away.”

The local levee district, meanwhile, has proposed expanding an existing levee all the way around the island, a consolation prize that may alleviate some of the tidal problems but not the risk from hurricanes.

One day in early spring, Albert

and his brother Pierre took a small boat out on the marsh in search of a graveyard. The island has one, a small plot on the west side of the bayou where dozens of people are buried, with some stones dating to the 19th century.

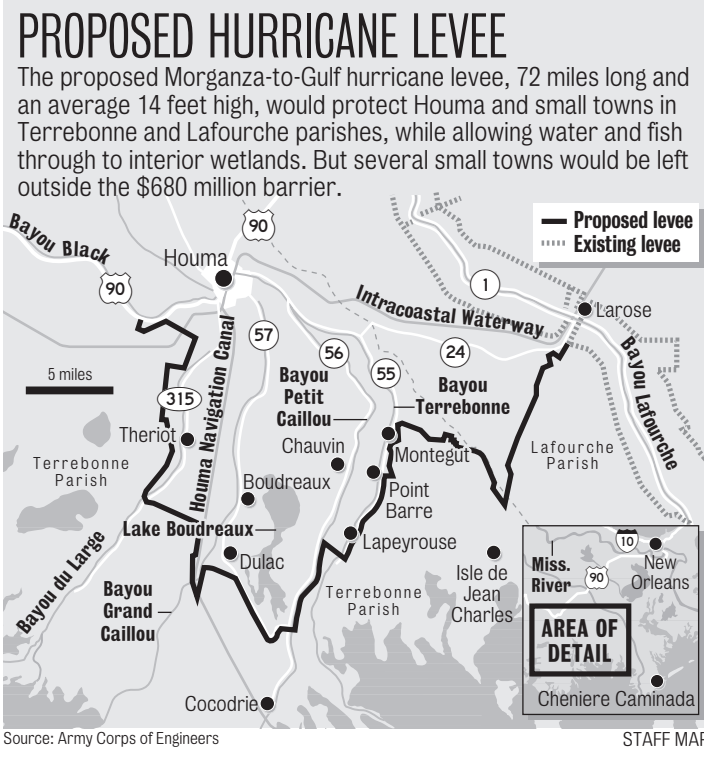
But the bones of ancestors are also found throughout the bayous in scattered plots, one of which he particularly remembered from his childhood, although he could not name anyone buried there.

For half an hour, the Naquins puttered up and down the bayou, scanning the grass on the western bank, looking for a white cross he remembered.

They spied the cross behind the soaring arch of a denuded cypress. They pulled the boat up to the bank and Albert Naquin hiked over the grass, squeezing water from the mud with each step. All that was left of the graveyard was the gate with the cross, still white but flecked with rust, and a low fence running part of the way around the high grass and bushes. No headstones remained.

An Indian fisher paddled a boat up the bayou past the Naquins. “There’s another one over there,” he said in French. “But you can’t find it anymore.”

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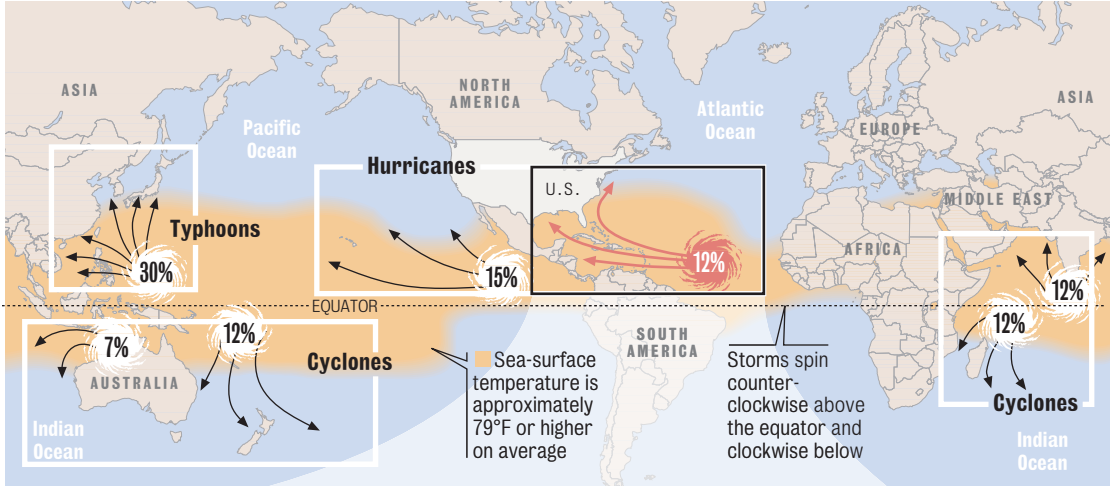
WASHING AWAY

NUMBERS GAME

Each year the world's tropical waters spawn a little more than 50 cyclonic storms that earn the label of hurricane, typhoon or cyclone. The chance of one hitting New Orleans may seem low, but history says we're due.

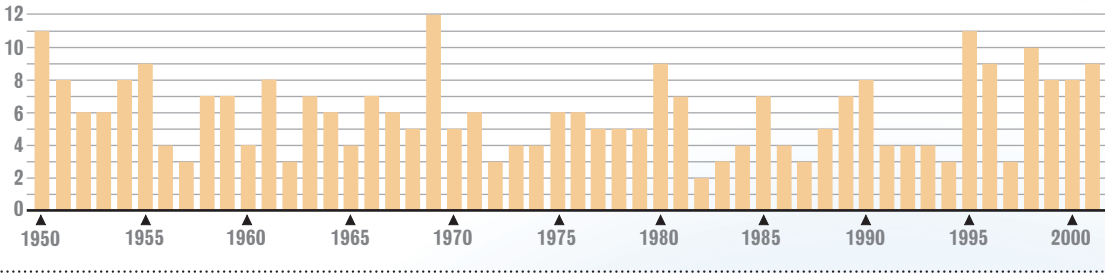
STARTING IN THE ATLANTIC ...

While vast populations in Southeast Asia are at risk from the highest number of storms, the costliest hurricanes come ashore on the developed coasts of the Caribbean and the southeastern United States.



Spawning ground

About 60 percent of all Atlantic tropical storms turn into hurricanes — 6 in an average year:

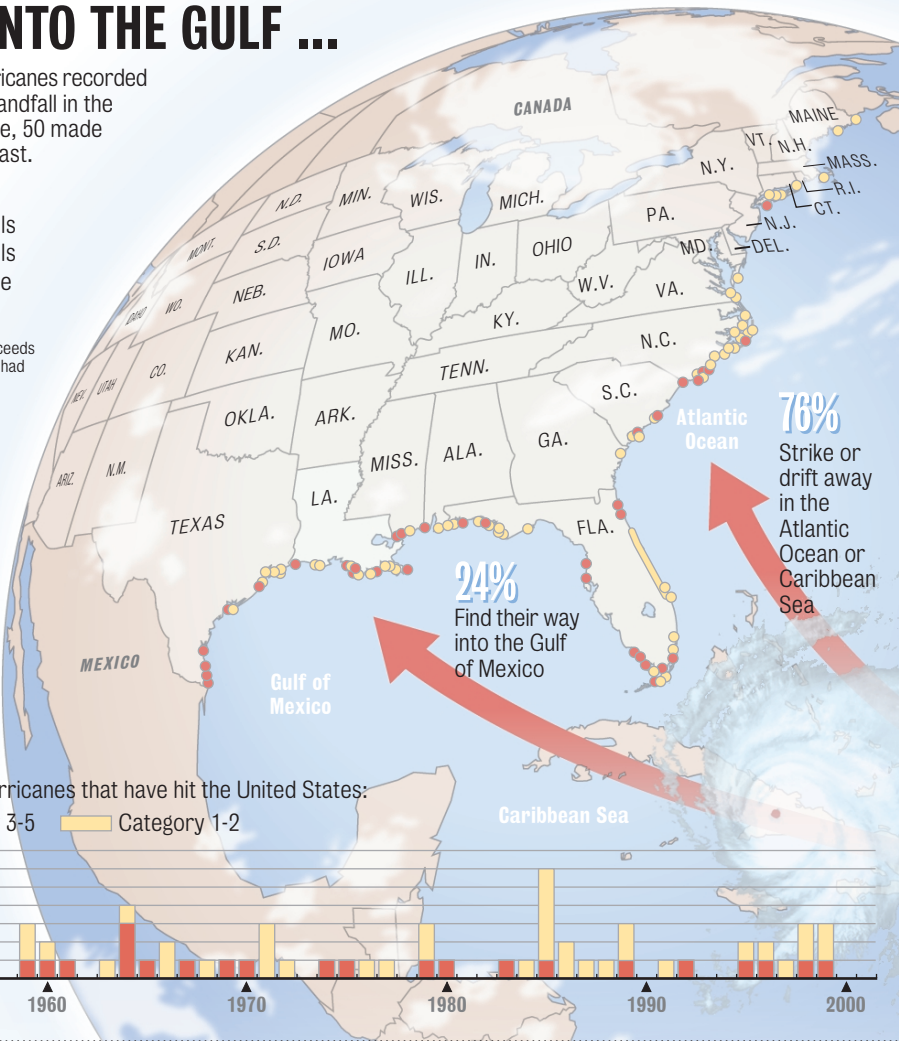


VEERING INTO THE GULF ...

Of the 314 Atlantic hurricanes recorded since 1950, 72 made landfall in the United States. Of those, 50 made landfall on the Gulf Coast.

KEY:
● Category 3-5 landfalls
● Category 1-2 landfalls
● Category 2 hurricane skirted the coast

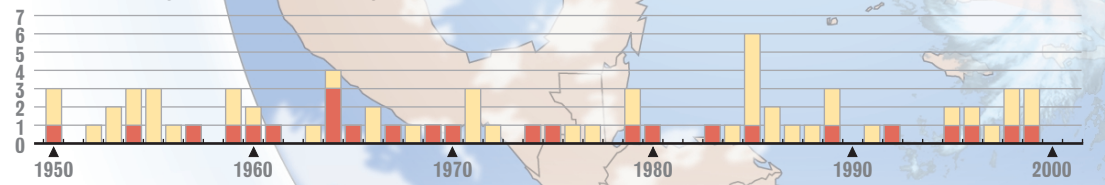
Note: Total number of dots exceeds 72 because some storms have had multiple landfalls



U.S. landfalls

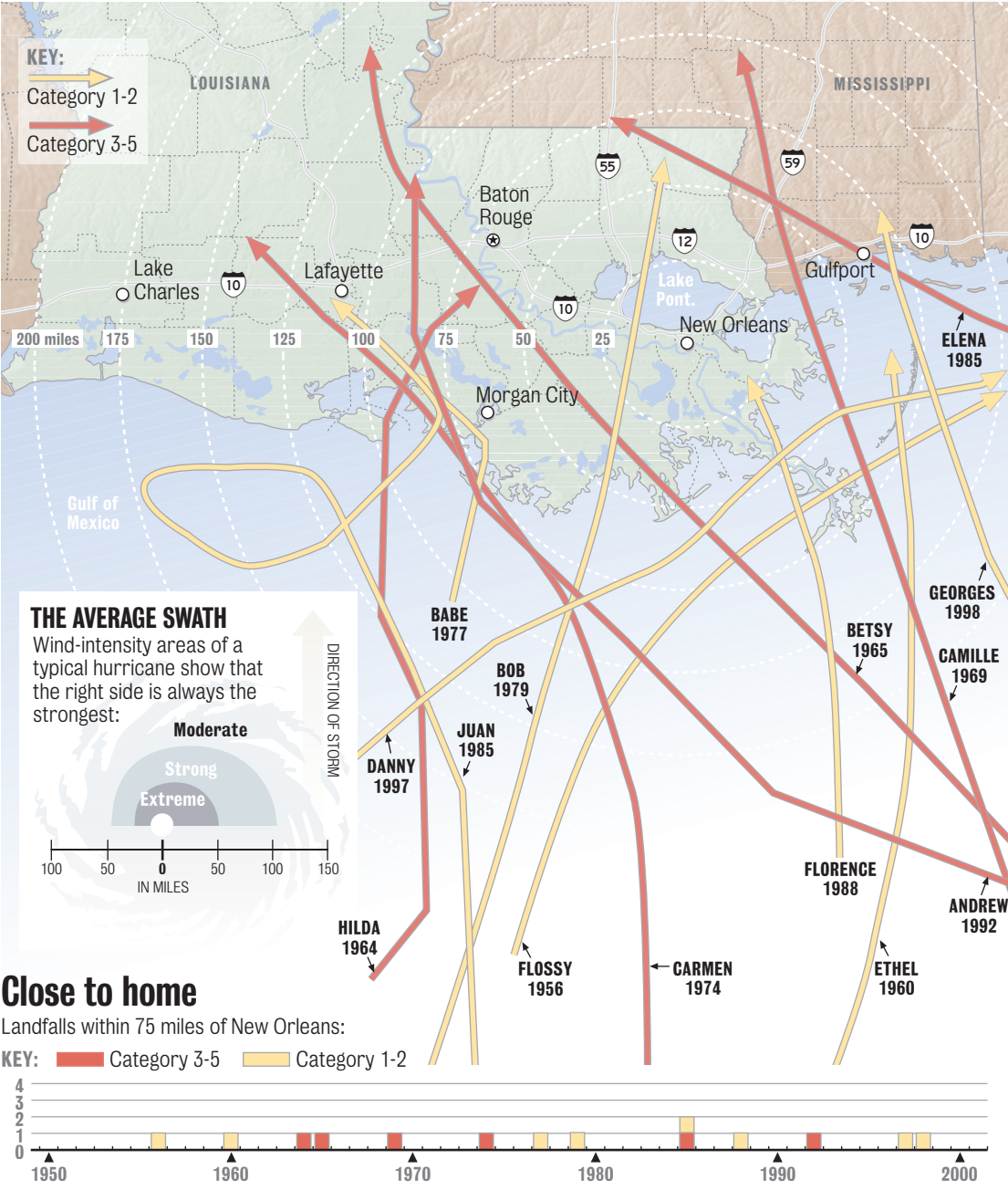
Number of Atlantic hurricanes that have hit the United States:

KEY: ■ Category 3-5 ■ Category 1-2



... AND BEARING DOWN ON NEW ORLEANS

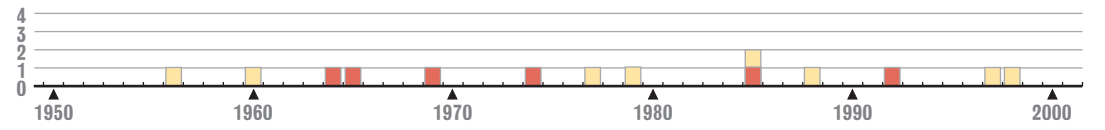
Since 1950, 14 hurricanes have made landfall within 75 miles of New Orleans. Five of them were Category 3 or greater, with winds topping 111 mph. One, Betsy in 1965, was a major hit. Two were close calls: Camille in 1969 and Andrew in 1992.



Close to home

Landfalls within 75 miles of New Orleans:

KEY: ■ Category 3-5 ■ Category 1-2



Sources: Unisys Corp., National Hurricane Center, Sun-Sentinel, staff research

STAFF GRAPHIC BY DANIEL SWENSON/dswenson@timespicayune.com

Despite rising hurricane risks, the Army Corps of Engineers hasn't revised its levee designs for the New Orleans area, and some areas may be more vulnerable to floods than the corps maintains.

Evolving danger

By John McQuaid and Mark Schleifstein
Staff writers

THE New Orleans area's last line of defense against hurricane flooding is a 475-mile-long system of levees, locks, sea walls and floodgates averaging about 16 feet high. The Army Corps of Engineers says the system will protect the city and suburbs from a Category 3 hurricane that pushes in enough seawater to raise Lake Pontchartrain 11.5 feet above sea level — high over the head of anyone standing on the other side of a levee.

That margin of error is critical because a storm that pushes the lake any higher can force water over the top of the levees and inundate the city. The water could quickly rise 20 feet or higher. People would drown, possibly in great numbers.

The corps doesn't know what that safety margin is anymore.

Generally speaking, the corps says the powerful, slow-moving storms capable of

overwhelming the system are rare and the levees are safe. But corps engineers say their own safety estimates are out of date, and an independent analysis done for The Times-Picayune suggests some levees may provide less protection than the corps maintains. The corps' original levee specifications are based on calculations made in the early 1960s using the low-tech tools of the day — manual calculators, pencils and slide rules — and may never have been exactly right, corps officials say. Even if they were, corps officials and outside scientists say levees may provide less protection today than they were designed for because subsidence and coastal erosion have altered the landscape on which they were built.

The agency is undertaking a new study to reassess the level of protection and another to determine whether the levees need to be raised still higher. Measuring the risks of disaster is a technical feat that few understand. But such exercises are critical to the future of New Orleans. If the new corps study confirms that protection is less than previously thought, the answers could have major effects on issues such as flood insurance rates, future levee expansions, emergency planning, evacuation and long-term business decisions. Thanks to its low, flat profile and its location on the Gulf of Mexico, south Louisiana is more at risk from a major natural disaster than most other places in the country. The risk of a catastrophic levee-topping flood in New Orleans is roughly comparable to the risk of a major earthquake in Los Angeles. Because of coastal erosion and subsidence, that risk is growing. But judging that risk and how to protect against it can be difficult. Recent experience tends to confirm the idea that catastrophic hurricane floods are rare. Even if a powerful hurricane comes close to New Orleans, only certain storm tracks could flood all or part of the city and suburbs. Twelve storms rated Category 3 and above have hit the Louisiana coast in the

past 100 years, but only five produced major flooding in the New Orleans area. The levee system was built largely in response to those storms, to prevent or reduce flooding in similar events.

Analysts quantify the unthinkable

Statisticians typically define the risk that something bad will occur by "return periods," the amount of time it takes on average for a given event to recur. The more often something occurs, the higher the risk. For example, many flood-protection projects are designed to shield people from the "100-year flood," which occurs in a given place on average every 100 years. That means that in any single year, the risk of that occurring is 1 in a 100, or 1 percent. If the average time between floods is 50 years, then the annual risk is double that: 1 in 50, or 2 percent.

Such statistical methods have a central role in levee design. The Corps of Engineers' original specifications say the lake-front levees would protect the city from a 300-year flood, defined as 11.5 feet above sea level, not including waves that crest even higher. The levees surrounding St. Bernard and the east side of eastern New Orleans are rated for a 200-year flood. The hurricane levee in Lafourche Parish is designed for a 100-year flood.

At first glance, those risks appear remote: Less than a 1-in-200 chance in a given year sounds like pretty acceptable odds. But they actually conform to risks that most people consider relatively common. For U.S. residents, for example, the annual odds of being attacked with a deadly weapon are 1 in 261, according to statistics compiled by Larry Laudan, a philosophy of science researcher now at the National Autonomous University of Mexico, in "The Book of



STAFF PHOTO BY ELLIS LUCIA

“The city is exposed to as much as four times the risk of hurricane flooding as it is to river flooding. ... That’s always been an odd issue to me. Why would the government think that water from the lake is less dangerous than water from the river?”

JOSEPH SUHAYDA, LSU engineering professor

Risks.” The odds of someone older than 35 having a heart attack in a single year are 1 in 77. The odds of injuring oneself on a chair or bed are 1 in 400. By contrast, the chance of dying in an auto accident in a given year is 1 in 5,000, and the chance of dying in an airplane crash, 1 in 250,000.

The risk of hurricane flooding also is much higher than for river flooding, because the government has committed remarkable resources to protect the region from the river. The Mississippi River levees average more than 25 feet high and are rated for an 800-year flood. “The city is exposed to as much as four times the risk of hurricane flooding as it is to river flooding,” said Louisiana State University engineering professor Joseph Suhayda. “That’s always been an odd issue to me. Why would the government think that water from the lake is less dangerous than water from the river?”

Scientists rely on the past

To design a hurricane-protection system, engineers must look at historical data and try to figure out how high and how often water will rise at certain points. Then they can figure out how high to build the levees.

It sounds straightforward, but it is a complex challenge. Accurate hurricane data go back only 100 to 150 years. Statistically speaking, not very many hurricanes have hit the New Orleans area — at least not enough to allow a solid projection into the future.

And the recent past isn't always an accurate basis for predicting the future. A Science magazine paper written last year by meteorologists William Gray, Christopher Landsea and Stanley Goldenberg predicted that based on long-term trends in sea-surface temperature, the Atlantic Ocean is entering a 10- to 40-year period of more intense hurricane activity. That

WASHING AWAY

means more big storms may menace areas that are more heavily populated than during the previous such cycle, from 1920 to 1960.

Storm surges are even harder to analyze. Flooding can vary dramatically mile by mile, even lot by lot, depending on the storm, rainfall, land elevation, levee heights and proximity to waterways and drainage pumps. Storm surges flowing into Lake Pontchartrain literally slosh around, first raising water heights to the north and west, then on the south shore. A record-setting rainfall could swell water heights by a foot or more, something that could turn a relatively weak storm into a killer.

Hurricane flood statistics are even spottier because scientists often did not have the equipment positioned in enough places to measure high water during past storms. The landscape also is changing because of coastal erosion, sinking and even levee building. So a flood height from the past wouldn't be the same today.

These were the challenges the corps faced in the early 1960s when it determined most of the current levee heights around New Orleans without computers or modern knowledge of hurricane dynamics.

Engineers wanted to prevent a repeat of the flooding that hurricanes in 1915 and 1947 had caused in the city, according to Jay Combe, the coastal engineering chief for the New Orleans district of the corps. They needed a single, hypothetical storm to use in the design process, something that embodied the worst flooding conditions the area had experienced.

So they mixed and matched features of both earlier storms to devise something called the Standard Project Hurricane. The levees would be built to protect against that imaginary storm.

Models envision the perfect storm

Meteorologists today say the Standard Project Hurricane could not exist in nature. It had a barometric pressure of 27.6 inches, the equivalent of a powerful Category 4 hurricane on today's Saffir-Simpson scale. But its maximum sustained winds were 100 mph, the equivalent of a relatively weak Category 2 hurricane. After running computer simulations in recent years, corps officials say the Standard Project Hurricane corresponds to a fast-moving Category 3 storm.

When they tried to predict how high a storm surge their imaginary storm would generate, engineers found the answers didn't match up with reality, Combe said. An estimate based on a statistical analysis of real floods showed higher storm surges were likely. So the engineers combined those two results. They decided the levees would protect against a potential flood of 11.5 feet above sea level. On top of that, they added several feet of "freeboard" to block higher waves from washing over the top, along with calibrated sloping, rocks and other features to reduce wave heights.

Combe defends the methods even while admitting that modern technology, and perhaps changes in the landscape, make them outdated. "Given the state of the art, the computing resources of the time, they did a crackerjack job," he said.

Butler basically agrees. "Those estimates are outdated, but they were very conservative," he said.

Today, engineers can fill in many of the gaps in the hurricane and flood data that challenged designers 40 years ago. Using computer models that incorporate current knowledge of hurricane and flooding dynamics, they can simulate past hurricanes in a modern landscape.

Then they can set levee heights to whatever level they find necessary, corps engineers are using such methods to reanalyze the levee system in the agency's new study. Butler, the engineer retained by The Times-Picayune, helped pioneer such methods as a division chief for the corps' Waterways Experiment Station in Vicksburg, Miss. He is now a principal partner of VeriTech Inc., an engineering consulting firm, also in Vicksburg.

Butler estimated flood risks around New Orleans and its neighboring suburbs.

He used historical flood information, his own modeling data and figures from a 1996 corps modeling study. The study was not completed in part because of disagreements between corps engineers and modelers over some results, which the modelers say are accurate. He crunched these in a statistical program to generate predictions of flooding at five points around the New Orleans area and compared that with levee heights to get a rough estimate of the risk of water coming over.

The results tend to confirm the corps' estimate of the level of protection along the lakefront, Butler said, although he said the exact risk could not be pinned down without more study.

He said the risks may be significantly higher than the corps maintains — perhaps double — on the

RAISING LEVEES

Since the 1700s, levees have been used to hold back the forces of Mother Nature. Today, they are higher than ever but still not enough to protect us from a major hurricane.



1908 • Workers using mules and horses haul dirt to raise a river levee in Jefferson Parish. Although the levees protected against river flooding, a 15-foot storm surge the next year from an unnamed hurricane killed 353 people and inundated much of south Louisiana.

CHENIERE HURRICANE CENTENNIAL



1979 • Workers pour a segment of the Orleans Marina floodwall. The wall was part of a Corps of Engineers project to extend hurricane-surge protection to New Orleanians living near Lake Pontchartrain. Each floodwall section, called a monolith, stood 11 feet high and was stabilized by pilings driven more than 35 feet into the ground

FILE PHOTO



2000 • Bobby Duthu helps build a floodwall being built on the edge of Bayou Segnette State Park near Westwego. The project is part of the \$90 million West Bank Hurricane Protection Levee that extends from Westwego to the Harvey Canal.

STAFF FILE PHOTO BY SUSAN POAG

east side along levees protecting eastern New Orleans, the Lower 9th Ward, Arabi and Chalmette. Where the corps says the levees protect against a 200-year flood, Butler says it's more like a 100-year flood.

Levee heights along the Mississippi River-Gulf Outlet and Intracoastal Waterway in the area range from 17.5 to 19 feet. Butler's estimates put the 100-year flood level at 16.3 feet above sea level, meaning waves on top of that would wash over the top and flood areas inside.

The historical record tends to confirm these results, Butler said. "All along the levee, there has been very high water measured there for several storms, certainly in Betsy. If you had the right kind of storm come in there, you'd really be in trouble."

Model's accuracy under fire

The corps agrees this is a weak spot because the area is closer and more open to the Gulf of Mexico than Lake Pontchartrain. "Flooding from a storm coming in on a track critical to New Orleans is more likely to occur in these areas outside the city," Combe said. "The MR-GO levee is more likely to be affected than the area in the lake itself."

Another reason flood heights tend to be higher there, Butler said, is that the levees protecting eastern New Orleans and St. Bernard converge in the shape of a V. When a storm pushes water into a narrowing space like that, the water tends to pile up and rise higher, increasing the risk of overtopping.

Combe and other corps officials

disagree with this assessment. They have a scientific dispute about the accuracy of the computer model both Butler and the corps use to simulate storm surges, called AdCirc for "Advanced Circulation Hydrodynamic Model."

corps engineers think it tends to overestimate flood heights in some areas, especially where two levees meet at an angle, Combe said. But computer modelers, including Butler and others, defend their results and say they have been corroborated by historical data.

Combe suggested the model doesn't account for a flow away from the levee at the bottom of the water column, something that would reduce the volume of water next to the levee — and the height.

University of Notre Dame engineer Joannes Westerink, one of the modelers Combe hired to work on the corps' current project, said he thought this effect would be relatively small. "Levees, land, a solid wall of buildings all cause storm surge to build up. But there is a return current: That effect does reduce it somewhat. . . . Is it 5 percent? Is it 2 percent? Is it 10 percent? Our best estimates are that it's on the low end," Westerink said.

Regardless, scientists in and out of the corps say a new study is necessary because of advances in technology and changes in the landscape. "We have lost acres and acres, square miles of land out there near the Gulf. So conditions and bathymetry (water depths) are different now," Combe said.

Why has it taken the corps this long to evaluate the problem? No clear bureaucratic mandate exists for reassessing the blueprints once levees are built. Congress appropriates money for levee construction based on corps studies that take years to complete. Dramatic changes or reassessments typically occur after major disasters, when political momentum generates for preventing a repeat.

"The government sort of does things strange," Combe said. "We do things in response to the direction of Congress and the president. Local sponsors say we need something done here, they pass a law, the president signs it, and we go to work. Going back later and looking at pieces of a project is something we have to look at, and we are looking at it and doing a more up-to-date analysis. We are in the process of redoing it. But the government wheels grind slow."

The disagreement over the computer analysis also dragged things out. A 1996 attempt to study Lake Pontchartrain-area levees broke down over that dispute and because of bureaucratic disagreements, according to Combe and others involved.

Meanwhile, sinking, erosion and sea-level rise mean that the odds of getting flooded have been getting worse across south Louisiana. "The frequency of flooding is increasing at all levels," Suhayda said. "You might find in 50 years that the risk of these infrequent events doubled. The 50-year event became a 25-year event, the 100-year event became a

50-year event."

'I'd get out of Dodge'

New avenues have opened for floodwaters entering the New Orleans area. The marshes and barrier islands of St. Bernard Parish have gradually disappeared, though not as much as in areas south of the city. As a result, more water can flow across them and into Lake Pontchartrain faster than 40 years ago. Since it opened in 1963, the MR-GO has eroded and widened to more than four times its original width in some areas. It now forms a giant sluice leading straight up to the city from the southeast, into the Intracoastal Waterway and ultimately into Lake Pontchartrain through the Inner Harbor Navigation Canal.

In any case, scientists say they want to know what the corps study finds, in part because they want to get a better grip on what the risks are for the sake of the city — and for their own peace of mind.

"I think everyone familiar with this is sitting on pins and needles because nothing has happened in that lake for 50 to 60 years and you start to think, are we due?" Butler said. "And the answer I think is yes, statistically you're due. And that's scary. Based on my knowledge of hurricanes, I'd watch what happens very closely — and I'd get out of Dodge."

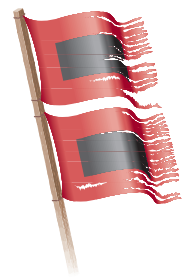
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WASHING AWAY

NATURE'S ULTIMATE WEAPON



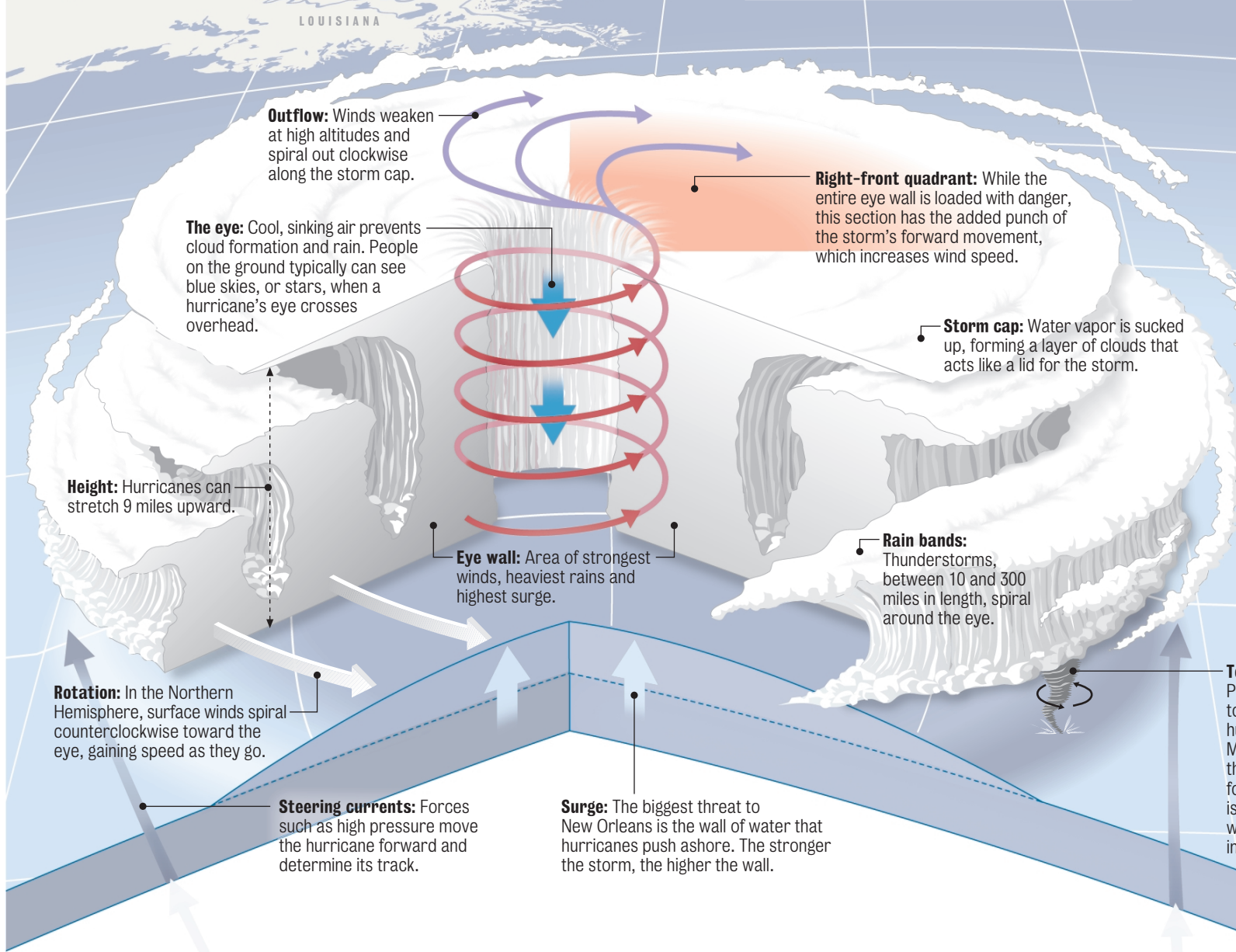
Whether they're called hurricanes, typhoons or cyclones, they are the most devastating weather events — churning masses of wind and rain that cause swaths of damage up to hundreds of miles wide at points along paths a thousand miles long. Beginning as thunderstorms in equatorial seas, the biggest storms can release as much energy as 15 atomic bombs and send walls of water 30 feet high surging into unprotected coastlines.

4 RAISE THE FLAGS: HURRICANES

About half of tropical storms take the final step to become hurricanes. A wall of thunderstorms contains violent winds of 74 mph or more. A clear, calm eye masks the biggest danger to an exposed, low-lying coast: The storm center's low pressure raises a dome of water as much as 30 feet high at landfall that surges forward along the storm's track.

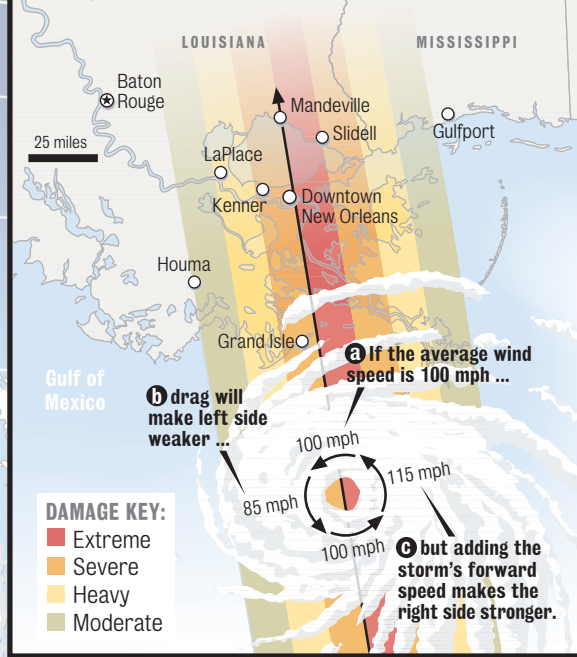
SAFIR-SIMPSON HURRICANE SCALE

Category	Winds (mph)	Surge (feet)	Damage
1	74-95	4-5	Light
2	96-110	5-8	Moderate
3	111-130	8-12	Extensive
4	131-155	12-18	Extreme
5	over 155	over 18	Catastrophic



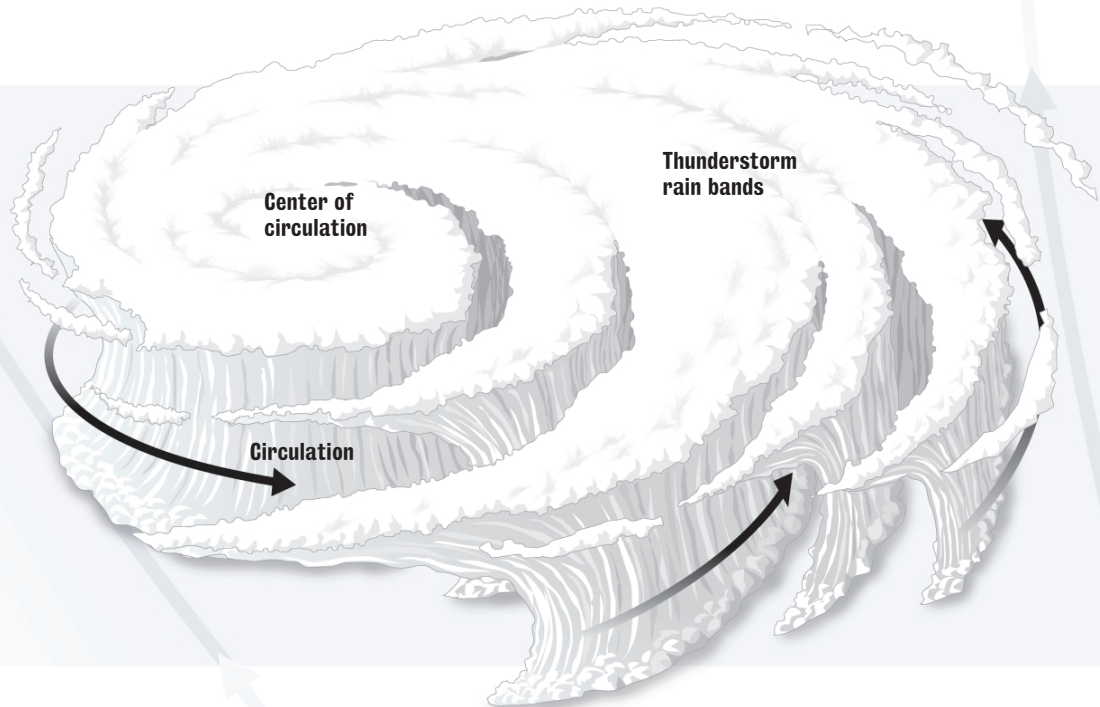
5 HEAD FOR SHELTER: MAKING LANDFALL

The right-front quadrant of the hurricane is the most dangerous. Winds can be 15 mph higher and the storm surge is greatest. Landfall weakens the storm immediately, cutting it off from a steady source of warm water.



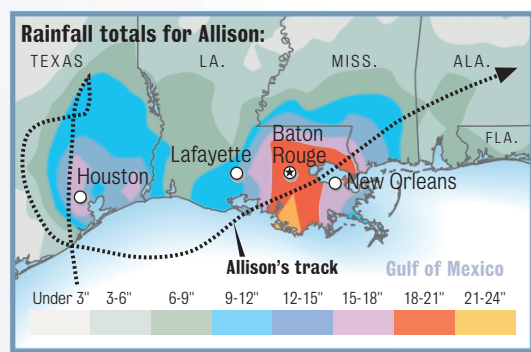
3 GET A NAME: TROPICAL STORMS

A visible center of circulation and winds of at least 39 mph earn the gathering storm a name. With slower forward speed, a tropical storm's worst damage results from its sustained, torrential rain — up to 40 inches is possible.



A LOOK BACK AT ALLISON

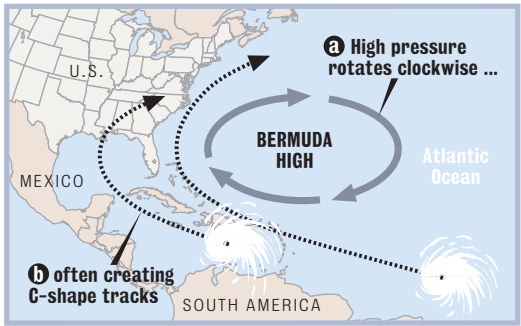
In June 2001, Tropical Storm Allison's deluge killed more than 30 people and made the record books, becoming the costliest tropical storm in U.S. history at \$5 billion.



DRIVING THE STORM

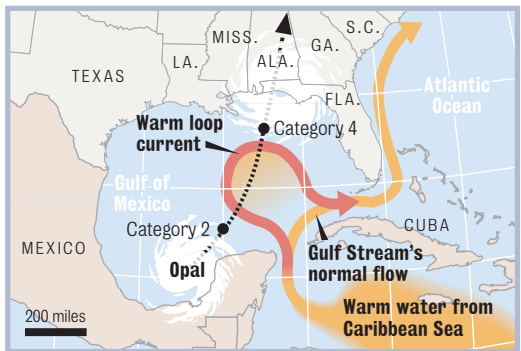
HIGH PRESSURE

Hurricanes often move around the clockwise rotation of a high-pressure zone called the Bermuda High. The spin of the Earth deflects the storm tracks in a giant curve.



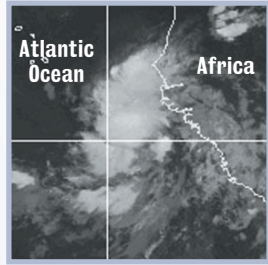
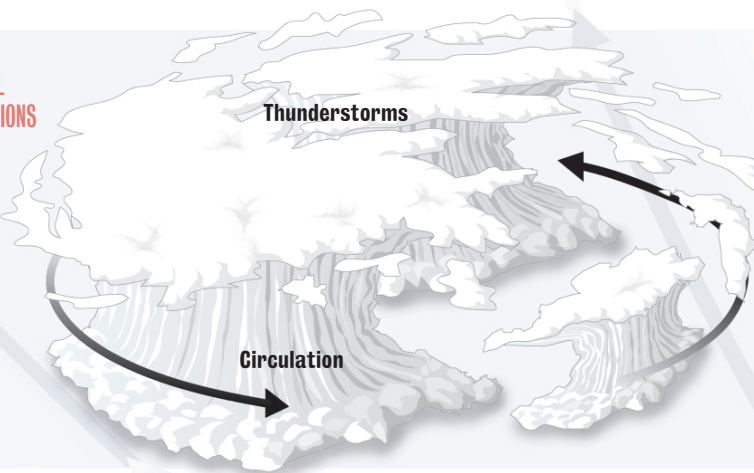
WARM WATER

For hurricanes that get into the Gulf of Mexico, a warm loop current, broken away from the Gulf Stream, can cause small storms to explode into monsters. This phenomenon strengthened Hurricane Opal in 1995.



2 TAKE A NUMBER: TROPICAL DEPRESSIONS

In northern latitudes, the Earth's spin sparks a counterclockwise rotation around the low-pressure center, where the larger thunderstorms congregate. If the storm holds together and the sustained winds hit 23 mph, a numbered tropical depression is born.

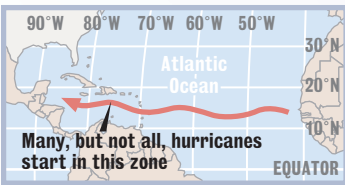


Some tropical depressions start as dust storms in Africa.

1 THE GATHERING STORM: TROPICAL WAVES

Fueled by warm ocean waters, bands of thunderstorms drift along the easterly trade winds in an area just north of the equator called the convergence zone. When the towering storm clouds come together for more than 24 hours, it's called a tropical depression.

CONVERGENCE ZONE



SEA SURFACE TEMPERATURE

